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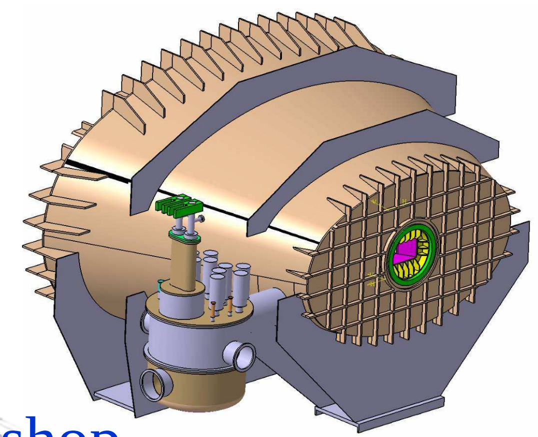
The R3B-GLAD Project

Bernard Gastineau
cea Saclay



2nd KEK-CEA Workshop
on superconducting magnets and cryogenics for accelerator frontier
Saclay, March 28, 2008

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R^3B

Reactions with Relativistic Radioactive Beams

Glad : GSI Large Acceptance Dipole

General view of the R3B-GLAD Project

- Introduction
- Main specifications
- Some technical challenges
- Some present activities

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The R³B collaboration

- 186 physicists
- 50 institutes
- 19 countries

The R³B Collaboration

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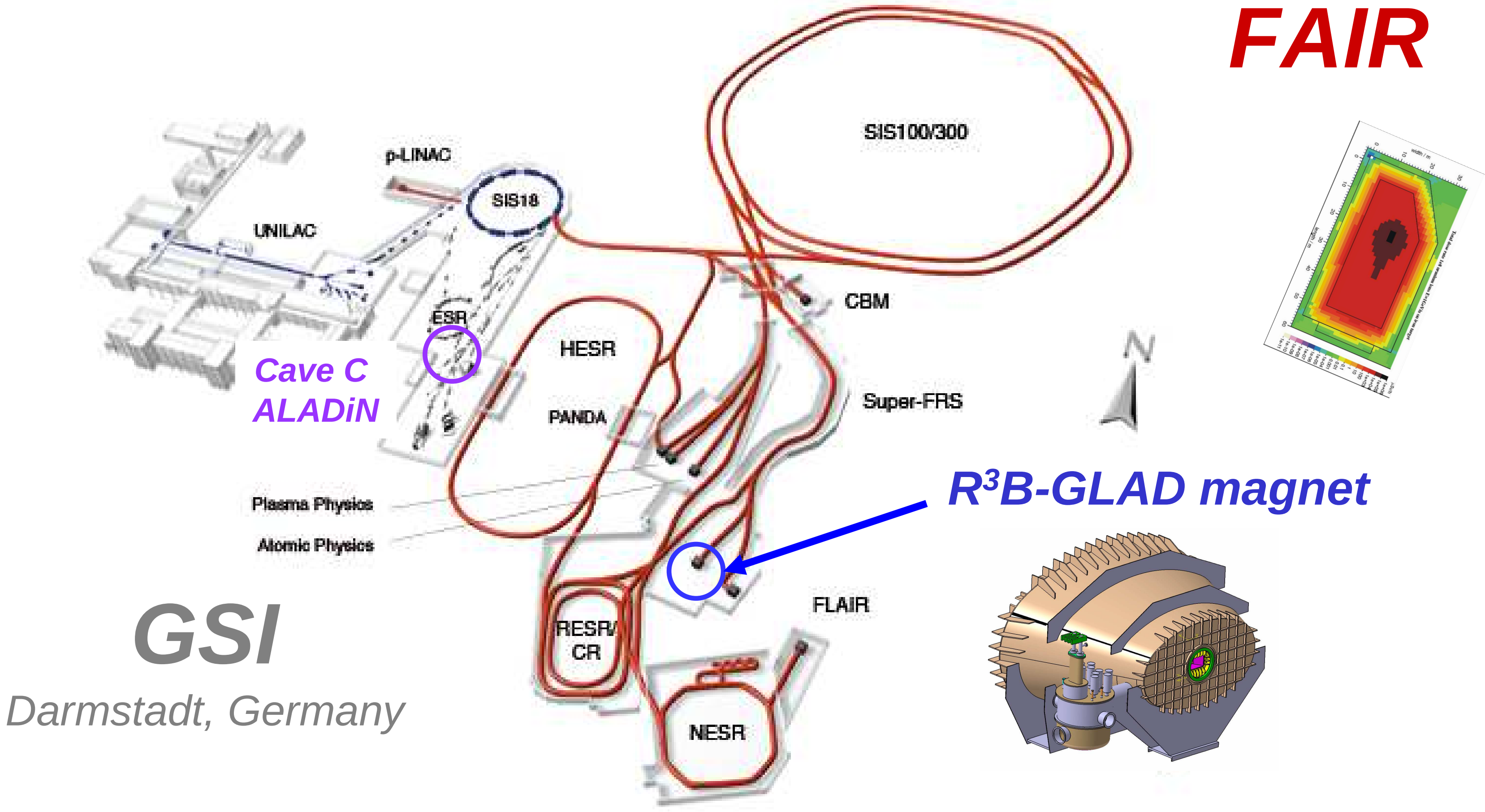
R3B Hall in the FAIR complex

Facility for Antiproton and Ion Research



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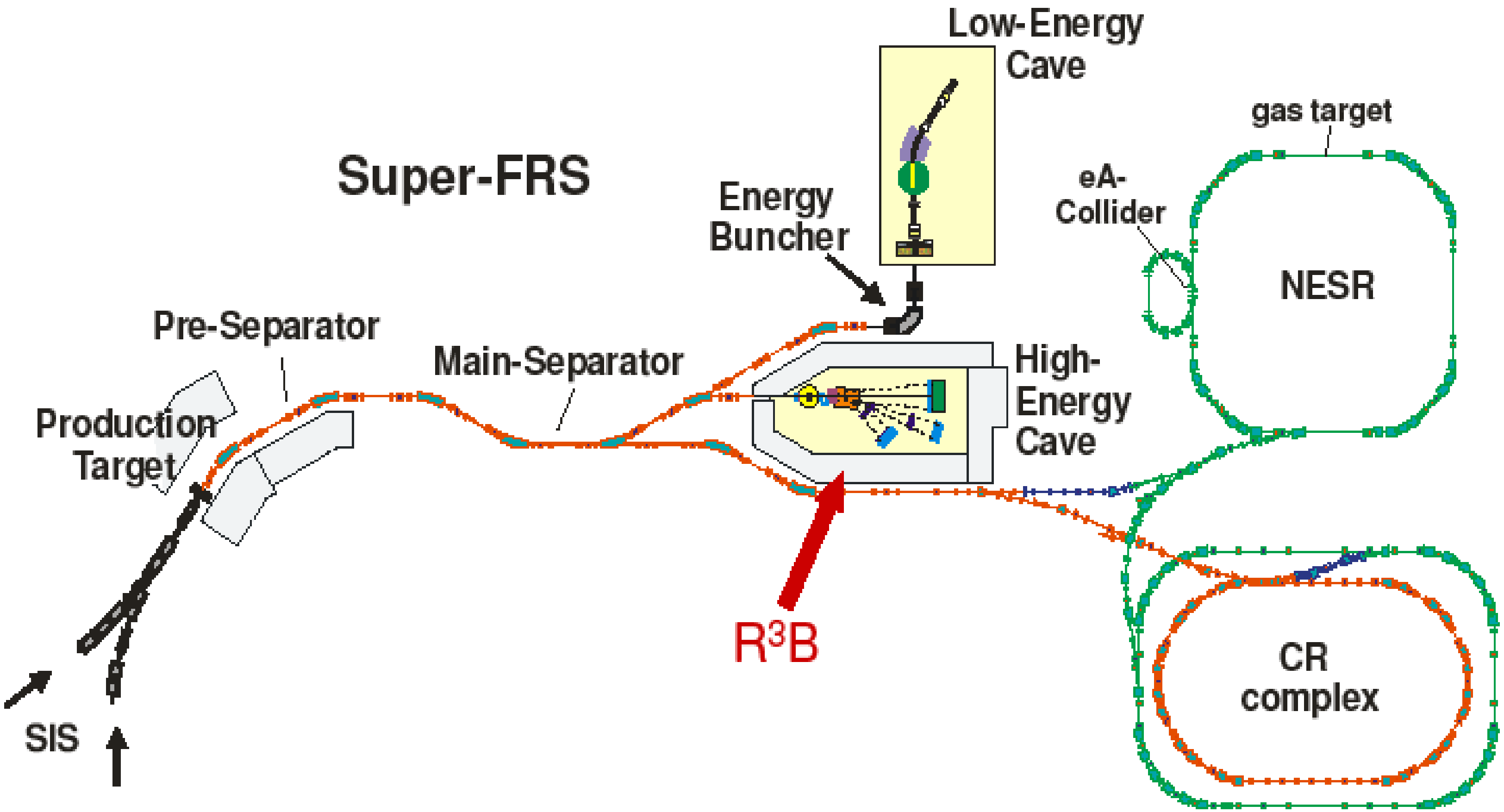
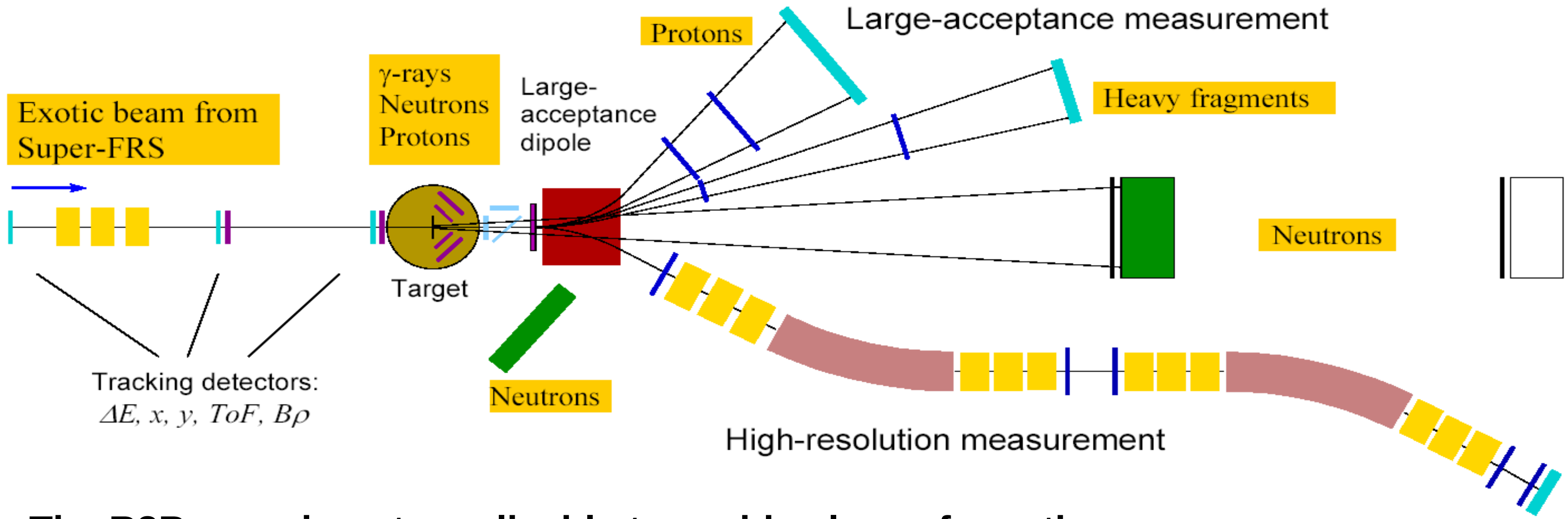
The NuSTAR radioactive beam facility
Nuclear Structure, Astrophysics, and Reactions



Reactions with Relativistic Radioactive Beams

R³B fully exclusive reactions measurements



-**The R3B experiment, applicable to a wide class of reactions :**

exclusive measurements of the final state

identification and momentum analysis of fragments

Large acceptance mode: $\Delta p/p \sim 10^{-3}$, High-resolution mode: $\Delta p/p \sim 10^{-4}$

- Coincident measurements of neutrons, protons, gamma-rays, light recoil particles

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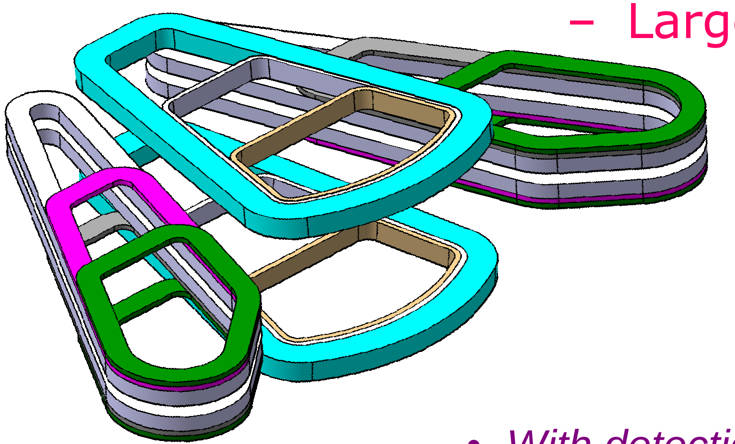
GLAD magnet challenges

Active shielding

superconducting magnet design

Specifications from the physics of R³B:

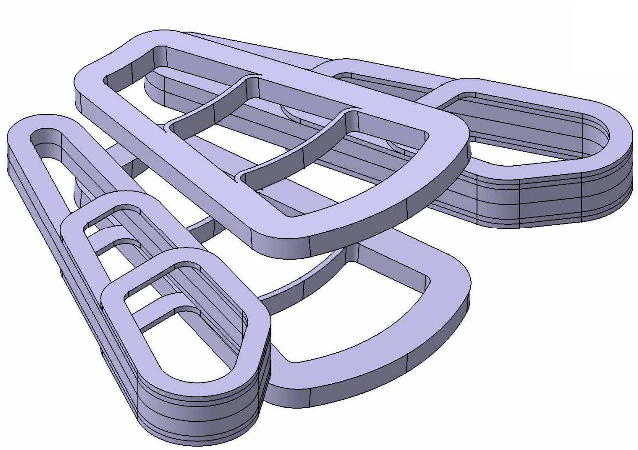
- Field integral 4,8 *T.m* → **18 *deg* of bending power** for ^{132}*Sn* ions at 1 *GeV* per nucleon
- Fringe field < 0.02 T around the target point
- Free detection volume around the target point: a ***sphere of radius*** *R = 1 m*
- Large acceptance:
  - **Opening angles**: +/- 80 mrad, horizontal & vertical for the neutrons and the charged fragments
  - Allowing the **detection in coincidence** of 1 GeV protons, neutrons and ions
  - Possibility of inverting the bending angle



- *With detection, overall momentum & angle resolution (10^{-3}, 1 mrad)*

R^3B large acceptance magnet design

- **Magnetic field integral: ~ 4.8 T.m**
- **Choices for the design of the magnet**
  - **Superconducting magnet**
    ⇒ ***Full linearity of the field with the current***
    ⇒ ***Lower operational cost (power consumption)***
  - **Active shielding technique:**
    $B \rightarrow 0$ rapidly outside the magnet



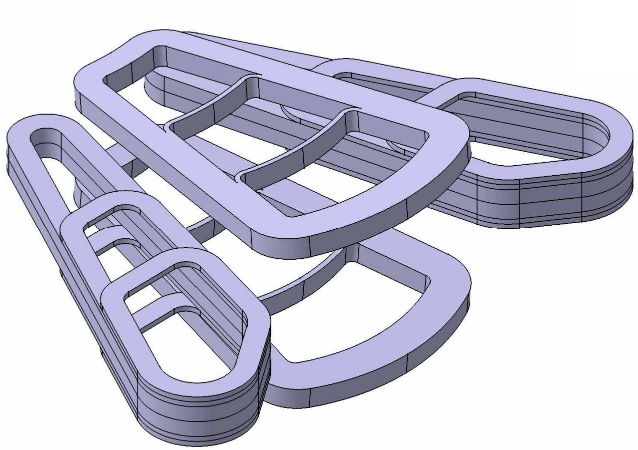
*One main feature of this butterfly-like magnet with graded, tilted and trapezoidal racetrack coils is the **active shielding** :*
It makes it possible to decreasing the field by two orders of magnitude within a 1.2 m length, despite the large opening on the outlet side of the magnet (around 0.8 square meters).

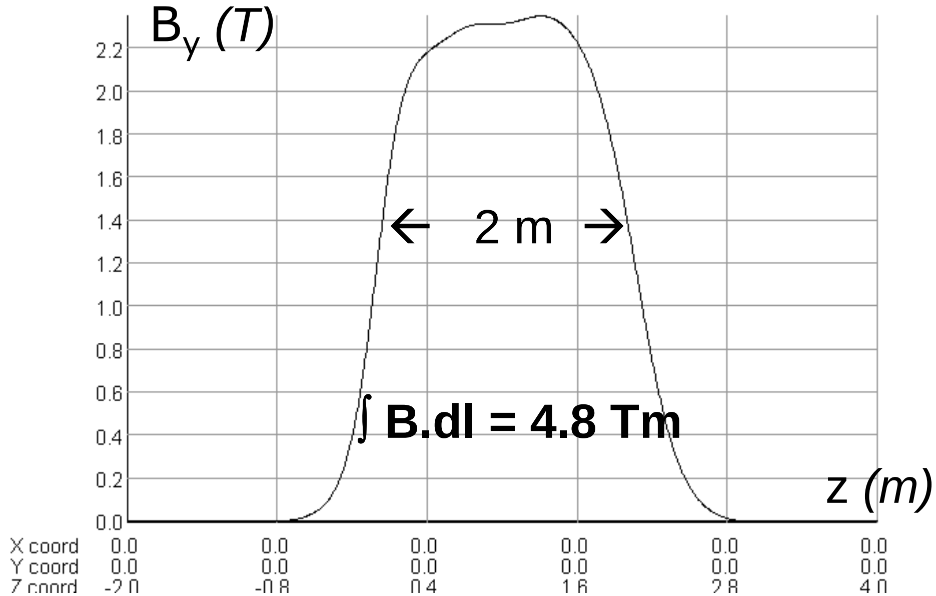
R³B large acceptance magnet design

- *Grading of the coils*
  - *Goal: Minimize the stored energy*

  ⇒ ***active magnetic volume as efficient as possible***

  (i.e. as close as possible to the particle trajectories)
  - ***While: Keeping as flat as possible the field profile along the symmetry axis of the magnet***





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Magnetic design study

The magnetic optimisation → final design of the coils (24 MJ)

*Different **criteria** were taken into account:*

-**reduction of the max field on the conductor** below 6.5 T
→ to increase the stability margin of the magnet,
- **minimising the fringe field** at the entrance & exit of the magnet
- **maximising the dipolar component** of the magnetic field on four different transverse planes
- **minimising the dispersion** of particle trajectories with the same momentum, in order to get the specified resolution
- keeping the field integral value equal to 4.8 Tm
- maintaining a **reasonable size** to the magnet.

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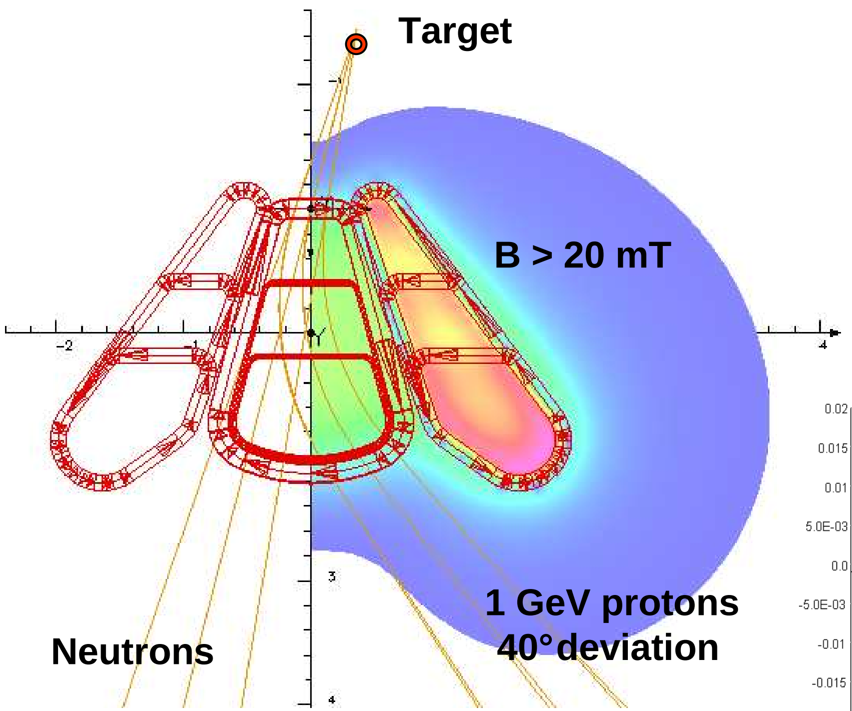
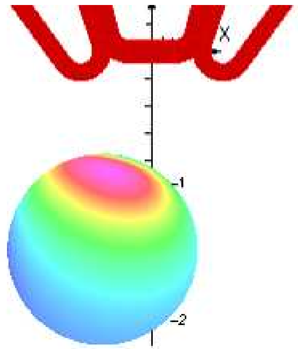
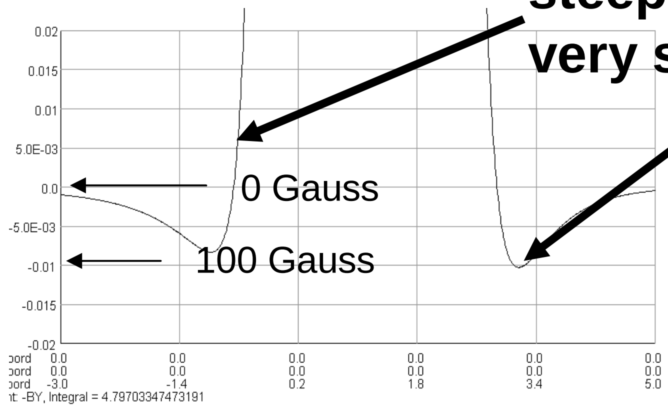
Magnetic design study - Results





Fringe field modulus in the target area:
< 220 Gauss
within R = 700 mm

Z dependence of By:
steep rise and fall with **very small bumps**



Active shielding : *Blimit ~ 0.02 T*

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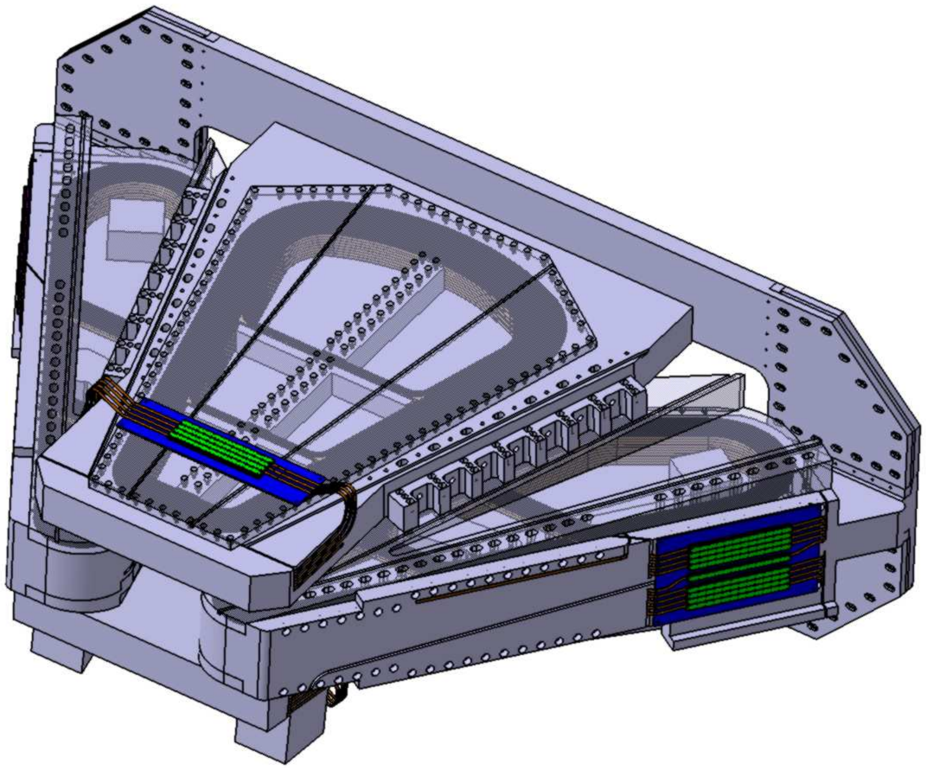
Main characteristics of the design

First,
a **high level of magnetic forces** (300 to 400 tons per meter), with little place to block the coils, requiring a very specific mechanical structure.

The coils are embedded in strong Al alloy (5083) boxes.



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Main characteristics of the design

Then, the **magnet protection system** based on an external dump resistor, coupled to a strong quenchback effect, to prevent any damage of the coils which could be caused by the **24 MJ** of stored energy.

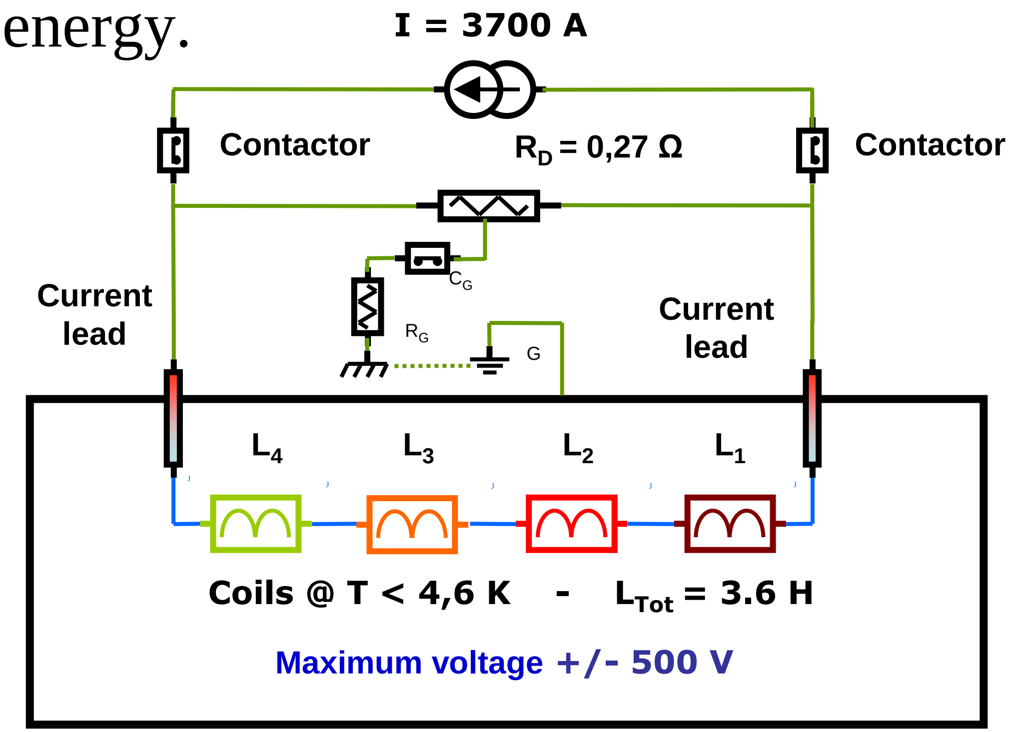
Main current 3700 A
Dump resistance 270 mW
Maximum Voltage +/- 500 V

Stored Energy 24.3 MJ
Inductance 3.56 H

Quench : *time const. 13.3 s*
Tmax < 150 K *max*

Conductor peakfield 6.35 T

Temperature margin ~ 1.5 K



Main characteristics of the design

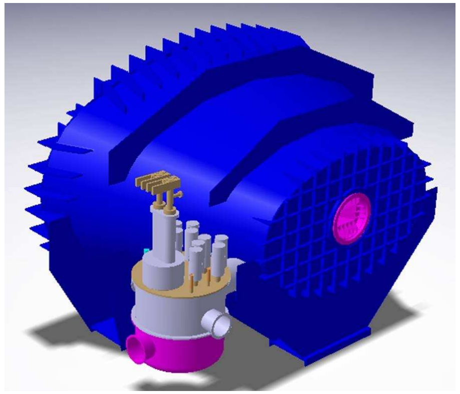
lastly, the **indirect cooling** of the cold mass with **two-phase helium thermosiphon** @ 4.4 K

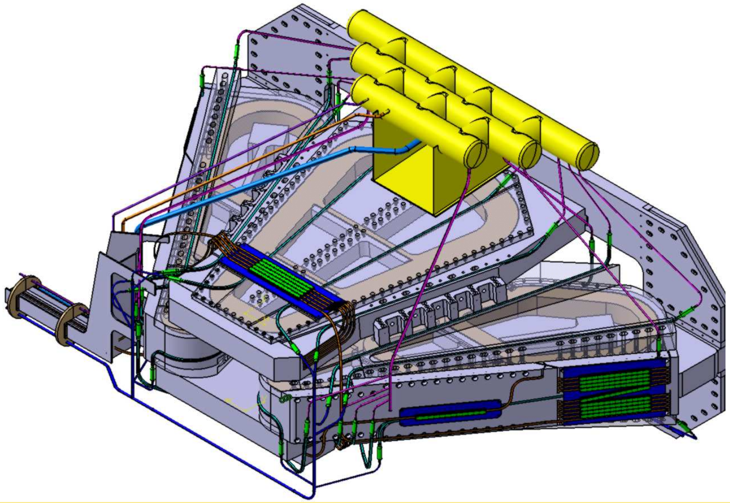
~ 20 parallel pipes; Thermal screen @ 50-80 K

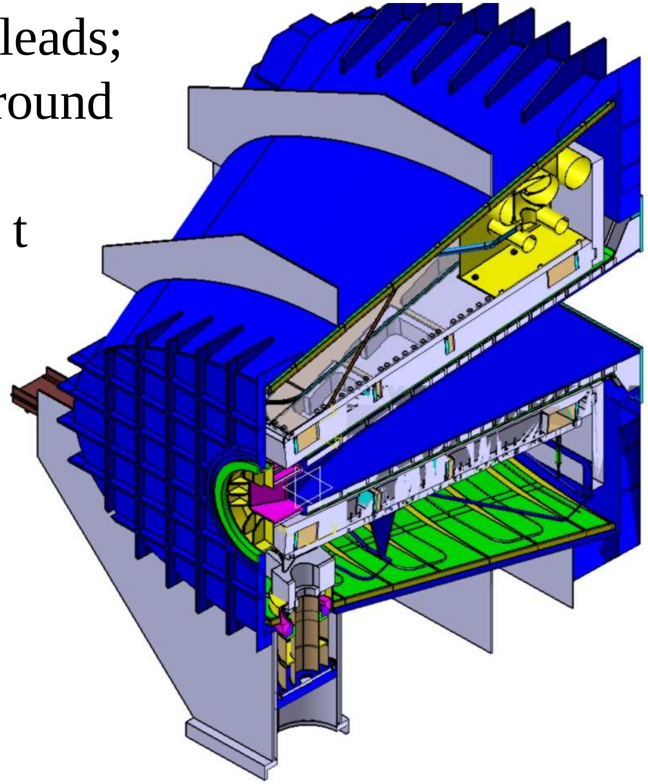
Coils: 28 double pancakes, ~30 joints, 2 current leads;

The overall size of the conical cryostat will be around 3.5 m long, 3.8 m high and **7 m** broad.

Total weight 50 t : conductor 4.5 t, cold mass 20 t



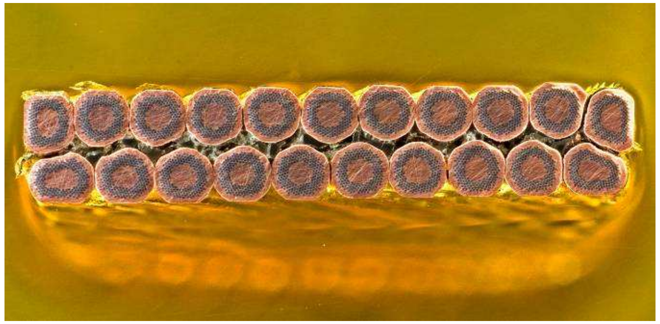




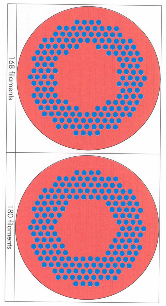
The superconducting cable

- The 4,5 tons of superconducting cable were ordered.
- Test lengths were accepted by CEA after qualification tests in May.
- The complete length of cable necessary for the coil winding has been delivered in January 2008.

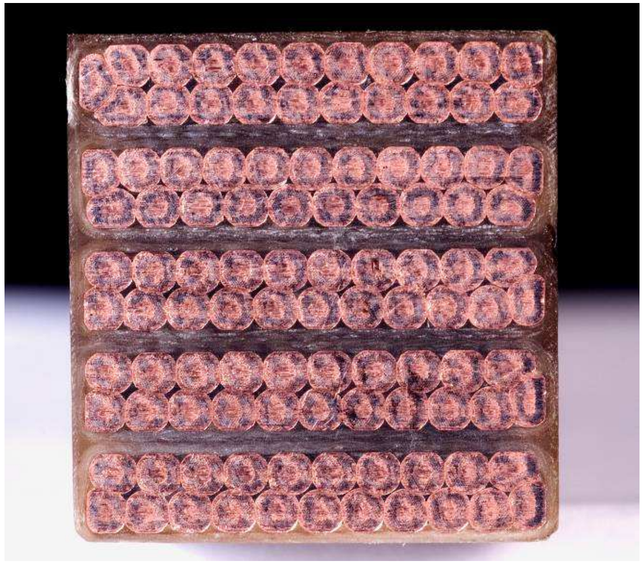
Conductor cable : Cu/NbTi = 2.6, Current density 75 A/mm2, Main current 3700 A



Rutherford cable, 21 strands
cross-section 15 x 2.6 mm^2



Stack of cables
after impregnation



Mechanical concerns

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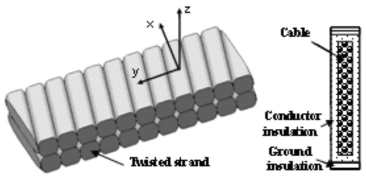
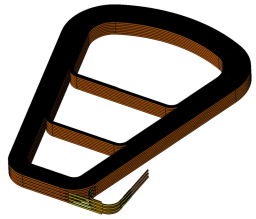
Estimated thermal shrinkage coefficients of the coil:





in the winding direction of the coil (x)

$\int_{300\ K-4\ K} \alpha_x = \mathbf{3.3} \pm \mathbf{?}$ mm/m,

in the transverse direction of the coil (y)

$\int_{300\ K-4\ K} \alpha_y = \mathbf{5.5} \pm \mathbf{?}$ mm/m,

in the vertical direction of the coil

$\int_{300\ K-4\ K} \alpha_z = \mathbf{6.8} \pm \mathbf{?}$ mm/m.

The orthotropic material properties of the coils (Cu stabilized, Cu/non-Cu = 2.6) are estimated by theoretical approach. Some assumptions have to be made during the homogenization process. Such as: the real shape of each strand inside the cable, the thickness of the insulation, etc.

Comparing with the $\int_{300\ K-4\ K} \alpha$ values of the isotropic metals :

Al alloy (5083)	Cu	Stainless steel (316L)
4.29 mm/m	3.37 mm/m	3.05 mm/m

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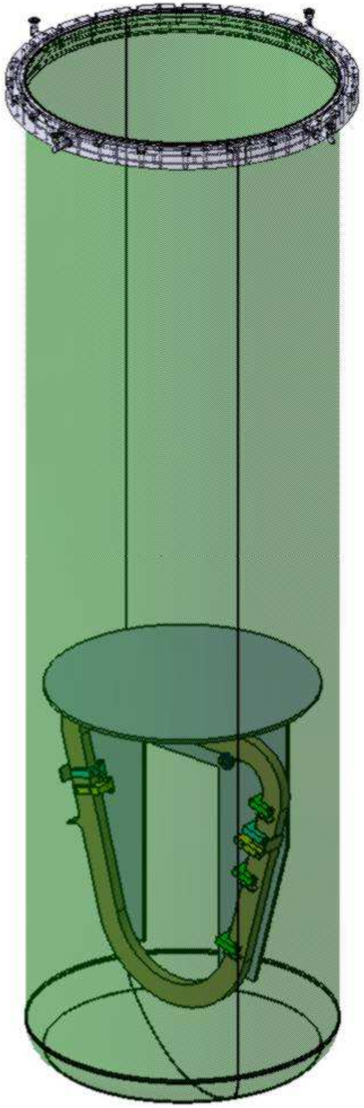


Mechanical measurements

Views of the thermal mock-up

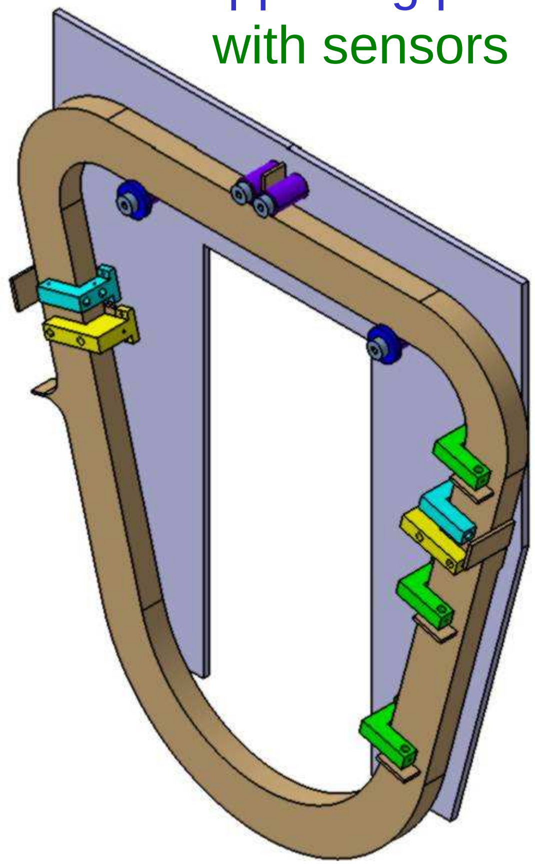
Tests on a thermal mock-up of the coils:

Measuring the thermal shrinkage on a coil of realistic dimensions

Test of the coil integration in realistic situation

In the test facility cryostat

supporting plate with sensors



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Activities in 2008

R&D programme on Thermosiphon cooling system

with “quasi” Horizontal cooling tubes

Delivery to GSI

The delivery of R3B-GLAD is planned for **2011, Q2**.

Thank you for your attention.